THE PRESERVATION OF BLOOD*

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WHEN THE PRESBYTERIAN HOSPITAL was considering the establishment of a Blood Bank, there was a demand for data as to what might be expected of preserved blood. It was appreciated that while the ultimate verdict would come from the clinical experience of its use, something of its potential dangers and benefits could be learned by preliminary work in the laboratory. Studies were, therefore, undertaken to find out what changes take place in preserved blood and the best methods of preserving it. This communication will summarize some of the findings but will of necessity omit description of methods, calculations, and other details.

To follow the deterioration of the cells, complete blood counts were made daily on blood preserved in a refrigerator at 4° C., with heparin as the anticoagulant. A similar series was made on citrated blood. The red cell counts varied, of course, but their mean remained about the same for 30 days in the heparinized blood. In citrated blood there was little change during the first 15 days, then a slow loss of from one to one and one-half million cells by the end of the month. According to Ponder, this loss is unimportant from a functional standpoint, as the capacity of the stored blood to carry oxygen remains unimpaired. The hemoglobin level remained constant, although increasing amounts of it up to 25 per cent were to be found in the plasma.

The mean cell diameter of the red cells steadily decreases from a base value of 7.6 to 5.8 microns at 35 days. The late loss could be due to escape of hemoglobin but this cannot account for the shrinkage of the first week which must depend upon salt and water loss.

Philip Levine[2] has submitted some interesting data on the length of life of a transfused red cell in the recipient. Identifying the donor cells in the patient by means of the group specific factors M and N, he found that cells stored 3, 10, or 14 days survived for 80, 60, or 20 days, respectively, as compared with cells of fresh blood, which lived over 95 days.

Volume index also decreased progressively—partly, perhaps, from the disappearance of white blood cells but mostly from the shrinkage in size of red cells.

The white blood corpuscle total count fell 50 per cent during the first 24 hours, and by the sixteenth day the cells remained only as smudges or amorphous masses. Polymorphonuclear leukocytes changed earliest and disinte-

* Read before the American Surgical Association, St. Louis, Mo., May 1, 2, 3, 1940.

grated most rapidly, but eosinophils and basophils were recognized distinctly as late as the thirty-fifth day.

The thrombocyte count fell rapidly to a low level, near which it remained for 15 days. The platelets of blood preserved in citrate solution had a slightly slower initial fall. Determinations of erythrocyte fragility gave poor end-points. It was clear, however, that cells on the tenth day were less resistant than on the first, and still less resistant on the thirtieth.

With these data in mind, it is apparent that the red cells of preserved blood can be depended upon to function satisfactorily. To transfuse stored blood for the sake of its white cells or platelets, however, would be a questionable procedure. If we think of the immune factors of blood as being associated with them, then the use of fresh blood for infection would be more logical.

The prothrombin percentage, as measured by the Quick method, after a prompt initial fall remains at 50 for a long period. In many cases this amount would be inadequate.

Of the several electrolytes of the blood, potassium is important as the chief mineral base of the red cells; in the serum, however, only one-twentieth of the amount in the cells is found. As has been observed before, plasma standing in contact with cells tends to be enriched with cell potassium. On measuring this diffusion process it was found that the rise of plasma potassium begins immediately the blood is withdrawn, continues at a rapid rate for the first few days, and then more slowly until equilibrium is established. This does not depend upon contamination.

Various preservatives modify the time at which hemolysis begins, and one (Peyton-Rous mixture) actually prevents it. But none of those recommended prevents potassium diffusion. The best record was made by a mixture of 0.3 Gm. of sodium citrate per 100 cc. The difference in rates at which cells lose potassium and hemoglobin shows that the latter is not a very sensitive criterion of cell deterioration. Nearly one-half the potassium had escaped from the cell before any of the larger hemoglobin molecules were lost. There is a real increase of plasma potassium as the result of shaking. In fresh blood this is not as pronounced as it is a few days later. Unavoidable transportation of preserved blood should be undertaken immediately rather than when it has become several days old.

While the material of the container was not proved to be of importance, the shape exerts a definite effect. Blood in an Erlenmeyer flask, for example, shows a more rapid rise in plasma potassium than blood in a test tube; in fact the rate of potassium diffusion varies as the diameter of the area where cells and plasma are in contact.

Investigation of placental blood by similar methods revealed that potassium leaves the cells at much the same rate. Another similarity was the superiority of an 0.31 per cent sodium citrate solution over the Russian citrate compound as a preservative. Judged by their rate of potassium loss, cells of placental blood deteriorate about as do adult cells.

Our interest in potassium was not purely as an index of loss of vitality of

red cells, but also for its possible toxicity. The intravenous minimum lethal dose of potassium for man is not known, and the acceptance of animal tolerance as a guarantee of safety is admittedly fallacious unless a comfortable margin of safety is provided. By analogy, then, three to five liters of blood with plasma containing 100 mg. per cent could cause the death of a healthy adult. However, animal tolerance for a potassium infusion is increased many times by administering it slowly. It is unlikely that so much blood would be infused except very slowly as a drip, and improbable that any harm would result.

In patients whose excretion is handicapped or whose serum potassium is already high, care in the use of aged blood is advisable. Particularly in hemorrhage and shock, where the tendency is to transfuse large amounts rapidly, one should use caution or fresh blood.

The higher values of plasma potassium in cadaver blood are striking. At the time of collection it is found at levels found in preserved blood on the fifth day. This could be due in part to the disease which produced death. Another factor is temperature. Diffusion of potassium is much more rapid at 38° than at 4° C., and a cadaver is not chilled as suddenly as is blood under the usual conditions of preservation. A further possibility is the formation of ammonia from breaking down of body proteins. Ammonia could increase cell permeability, as it does in certain plant cells.

Ammonia nitrogen is found in infinitesimal amounts in normal blood but rises rapidly in the first few minutes of exposure to air. It continues its marked rise for four days, to reach the level of 1 mg. per cent, where it remains until the tenth day.

The direction taken by the sodium ion is the opposite of that of potassium; the plasma sodium decreases as potassium rises. Evidently it diffuses from the plasma into the cells.

These changes due to diffusion depend upon the permeability of the cells. The process could be slowed if the increasing permeability of the cells could be retarded. The possibility that ammonia is in some measure responsible for this phenomenon suggests the use of carbon dioxide to slow ammonia production.

Comparison of blood collected under carbon dioxide for changes in potassium, sodium, ammonia-nitrogen, and p_H with a control specimen withdrawn in the air demonstrated that carbon dioxide is effectual in retarding the changes in the concentration of these bases and maintains the p_H nearer neutral.

The plasma calcium content remains constant for nine days even when shaken. Magnesium diffuses into the plasma so slowly that the amount accumulated in nine days is too small to have any toxic effect. Moderate trauma does not materially increase the rate.

Of the anions, the fall of plasma carbonates and chlorides and the rise of phosphates are apparently innocuous.

The statistics of reactions following transfusion cannot be briefly presented because of the necessity of detailed information as to criteria and technic.

However, with these two factors constant, only one difference in the incidence and severity of reaction between fresh citrated and stored citrated blood need be anticipated, namely, jaundice. This is transient and asymptomatic but frequently follows use of blood stored for nine or more days.

The outstanding changes of clinical interest taking place in stored blood are its loss of white blood cells and platelets, its increase in plasma potassium, and decrease in prothrombin. For most purposes it should give results comparable with fresh blood; for infection, prothrombin deficiency, and shock it would be inferior. Intelligently employed during the first week of storage, it need be neither dangerous nor disappointing.

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